iv. Experimental Vacuum Systems

Each experimental area as defined by the space between the beam pipe end flanges of the two DX magnets is 17.2 m in length. Each area, as shown in Fig. 4-4, is subtended by all-metal, rf-shielded gate valves, beam position monitors, bellows, sputter ion pumps and titanium sublimation pumps. The space available for the experimental beam pipes (EBPs) and detectors is approximately 14.2 m in length.

The beam pipes adjacent to the sputter ion pumps are RHIC standard 304L warm bore tubes with 12.7 cm OD x 3 mm wall and a 5:1 diameter transition down to 7.6 cm OD, followed by 7 cm ID rf-shielded bellows. To maximize the transparency for the experiments, the 1.5 m central sections of the EBPs for three experiments, STAR, PHENIX and BRAHMS, are made of beryllium (Be) with extensions made of either aluminum or stainless steel. The EBPs of PHOBOS consist of three 4m long Be pipes jointed together with Be flanges, bolts and nuts and aluminum gaskets. The outer diameter of Be sections for all four experiments is 7.6 cm and the nominal wall thickness 1 mm. The 7.4 cm ID of the EBP provides the required 10σ beam aperture (up to ± 5 m from IP) for all the RHIC operating conditions.

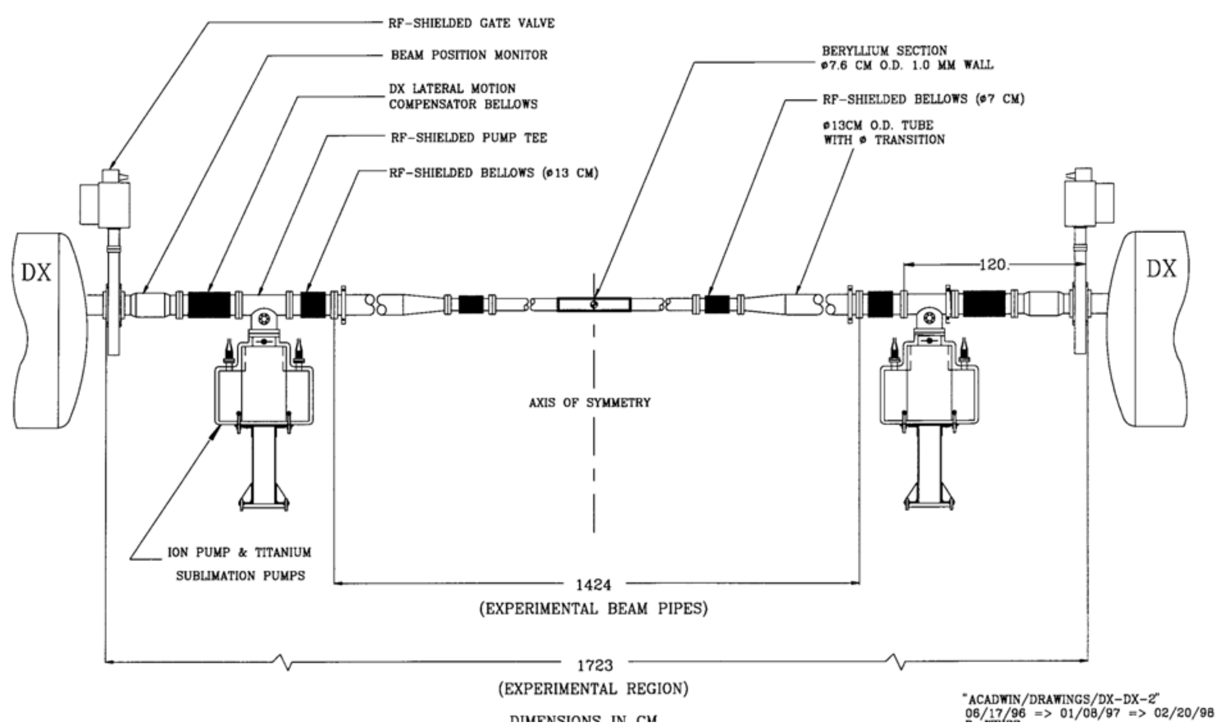

Fig. 4-4. Layout of the vacuum components at experimental regions.

Table 4-3. Experimental Beam Pipes

Experiment	EBP Length	Be Section	Extensions	Flange
STAR	8 m	1.5 m	A1uminum	A1/SS Conflat
PHENIX	5.2 m	1.5 m	Stainless Steel	SS Conflat
PHOBOS	12 m	3 × 4 m	None	Be Conflat
BRAHMS	7.1 m	1.5 m	A1uminum	A1/SS Conflat

The Be section is fabricated from Be sheet rolled into a tube with a longitudinal braze joint. The Be sections are brazed to stainless steel or aluminum extensions and then welded to the 12 cm OD Conflat flanges to form the complete EBPs. Table 4-3 lists the length of the EBPs, the length of the Be sections and the type of extensions and flanges for each experiment.

To achieve the design vacuum of low 10^{-10} Torr, the entire interaction region (from gate valve to gate valve) has been in-situ baked up to 250°C (up to 150°C for EBPs with aluminum extensions). In-situ bake is accomplished with custom heating blankets fitted around the EBPs and other vacuum components. In STAR where installation and removal of heating blankets is not possible after vacuum assembly, the EBP is only wrapped with three layers of 0.025mm thick Kapton foil as thermal insulation prior to installation into the detector. Heated dry nitrogen flow, from liquid nitrogen boil-off, is then used to bake the central section of the STAR EBP to approximately 100° C for 24 hours, to remove surface water and other contaminants. The in-situ bake of EBP region is monitored and controlled with integrated industrial temperature controllers. Bake outs are usually completed in 2-3 weeks, including the time for set up and removal of heating jackets and bakeout equipment, ramp and soak periods and TSP and ion pump conditioning.

The average pressure inside the EBPs after in-situ bake can be approximated by:

$$P_{avg} = \pi \; \mathrm{Dq} \left(\frac{\mathrm{L}}{\mathrm{S}} + \frac{\mathrm{L}^2}{3\mathrm{C}} \right)$$

with D the diameter of the EBP, q the unit outgassing rate, $2S$ the pumping speed (i.e., $S = 500$ l/s), $2L$ the distance between the pumps ($L = 775$ cm) and C the linear conductance (~ $2\mathrm{x}10^4$ l.cm/sec for

H_2 and ~ 5x10^3 *l*.cm/sec for CO of 7.4cm ID pipe). Therefore, the average pressure will be ~ 10 times higher than that indicated by the gauges located at the pumps. The outgassing rate of the EBPs is much below 1x10^{-12} Torr·*l* /sec·cm^2 after the in-situ bake, and average pressure of 10^{-11} Torr has been routinely achieved without beam.

Pressure rise of a few decades have been observed at all EBP regions during recent high intensity operations with shorter bunch spacing, resulted from beam induced desorption and electron cloud induced desorption. This pressure rise has caused high beam loss as well as high detector background. NEG coating of the EBPs is proposed to combat the pressure rise. NEG coated surface has lower secondary electron emission as compared with stainless, aluminum, and especially beryllium which has a peak SEY of 2.8, therefore increase the electron cloud threshold. If properly activated, NEG surface will also have very low electron stimulated desorption and provide very large linear pumping speed thus further reduce the pressure rise. The low activation temperature (~ 200^{o}C) Zr-V-Ti alloy NEG coating developed by CERN may be applied using magnetron sputtering. The small ID and the long length of the EBPs, as listed in Table 4-3, make the NEG coating rather challenging. The vendor for the NEG coating of the 12cm Φ insertion beam pipes can't handle beryllium and the potential residual radiation. Either in-house developed coating or CERN LHC coating facility may be used to coat these pipes. Development of a horizontal cathode coating facility for the EBPs is underway. A careful risk assessment is required if the EBPs are transported to CERN for coating. Proper activation of the NEG in EBP at the interaction regions also needs further development since both STAR and Brahms pipes have aluminum extensions and could not be heated safely in the installed position at higher than 100^o C and 150^o C, respectively. Methods of re-activation after saturation also need to be developed, since all the heating blankets in Phenix, Phobos and Brahms are removed after in-situ bake.